to give the results of this study here as they verify the results obtained by Moltschanoff in this connection.

In this study 418 two-theodolite observations made at various aerological stations in the United States were selected. The only criterion used in the selection was that they be taken early in the morning so as to exclude the effects of thermal convection. Consequently only observations taken before 8 a. m. were used. The balloons weighed 25 to 35 grams and were filled to give an ascensional rate of 180 meters per minute or to a free lift of from 120 to 130 grams, depending upon their weight. The velocity of the wind was correlated with the ascensional rate for each of the first four minutes of the observations, i. e., the velocity of the wind at the end of the first minute was correlated with the ascensional rate during the first minute, the velocity of the wind at the end of the second minute was correlated with the ascensional rate of the balloon during the second minute, etc. There was found to be a direct relation between the ascensional rate and the wind velocity during the first minute. The second minute showed a mere suggestion of a relation and the third and fourth minutes no relation whatever. The correlation coefficients and probable errors for the first, second, third, and fourth minutes were found to be $+0.507 \pm 0.024$, $+0.172 \pm 0.032$, $+0.012 \pm 0.033$, and $+0.008 \pm 0.033$.

It may be of interest also to know that the average ascensional rates for the first four minutes were, 198.4, 180.5, 178.0, and 179.1 meters per minute, respectively, and the standard deviations from these averages were 18.7, 15.8, 16.1, and 15.6 meters, respectively.

It is noted that the results of this investigation are in close agreement with those given by Moltchanoff with balloons of approximately the same free lift. Investigations of the ascensional rate of pilot balloons (*3*) made by Capt. B. J. Sherry are also in accord with the results obtained by Moltschanoff in so far as the effect of wind velocity on the ascensional rate is concerned.

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## THE WIND FACTOR AND THE AIR MAIL SOUTHWARD FROM KANSAS CITY

551.55:(764)(781)
629.13

By JOHN A. RILEY

[Weather Bureau Office, Broken Arrow, Okla., January 20, 1926]

[Presented before the American Meteorological Society at Kansas City, Mo., December 28, 1925]

The Air Mail route southward from Kansas City extends first in a west-southwesterly direction to Wichita, thence southward to Oklahoma City, and from there slightly east of south to the Dallas-Fort Worth landing field midway between these two cities. The distance from Kansas City to Wichita is approximately 180 miles, Wichita to Oklahoma City 155 miles, and Oklahoma City to Dallas-Fort Worth 190 miles. The southbound mail leaves Kansas City at 11:20 a. m. and arrives at Dallas-Fort Worth at 5:40 p. m. The northbound mail leaves Dallas-Fort Worth at 8 a. m. and arrives at Kansas City at 2.15 p. m. This schedule calls for a speed of about 90 miles per hour in each direction.

In dealing with the wind factor in flight it is generally recognized among flying men that the normal state of the air is one of more or less rapid movement, subject to frequent changes of speed and direction. And although the wind is scarcely ever strong enough to prevent a flight it is sufficient to affect schedules by causing delays. The wind also tends either to reduce or to increase the average speed of flight and this effect increases as the velocity of the wind approaches the speed of the craft.

When we know the speed and direction of the wind and the cruising speed of the craft the resultant speed is readily computed. We first find the angle the craft must make with the course to overcome the effect of drift. This is called the $\beta$ angle; the angle between the wind and the course is the $\alpha$ angle. $\beta$ is found by the formula,

$$\sin \beta = \frac{S_w}{S_a} \sin \alpha$$

in which $S_w$ and $S_a$ are the wind speed and the craft speed, respectively. In flying where no landmarks are visible, as above clouds or over water surfaces out of sight of land, this angle must be computed or estimated. After it is obtained the resultant speed of craft is found by the formula [1]

$$S_r = S_a \cos \beta \pm S_w \cos \alpha$$

Figure 1 represents the surface winds at Broken Arrow. It is based on a five-year period of continuous hourly records. The average speed and the percentage frequency of the eight directions are shown.

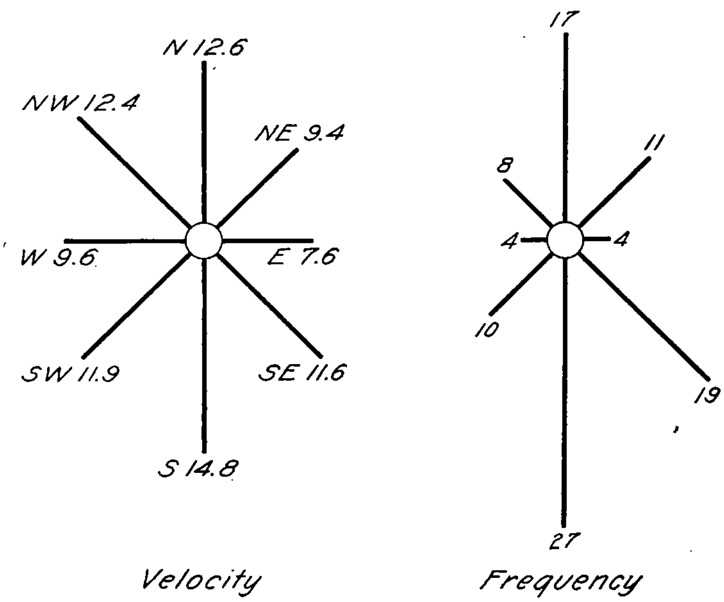


FIG. 1.—Average annual velocity (m. p. h.) and percentage frequency of surface winds, Broken Arrow, Okla., based on continuous automatic records

[1] Graphs for readily obtaining these data as well as other information of practical value in aerial navigation may be found in a paper "The weather factor in aeronautics," by Dr. C. L. Meisinger, who was until his death a pioneer in aeronautical meteorology. (Mo. Wea. Rev., Dec., 1920.)

In a previous study wind data were published for Fort Sill, Okla., and Groesbeck, Tex., as well as for Broken Arrow (*1*). Close similarity was found to exist in the surface and free-air winds at flying levels at the three places. The free-air data in the present paper are based on a six-year record of daily pilot-balloon ascents at Broken Arrow.

While Broken Arrow is not on the air mail route, which passes considerably to the westward, it is near the half-way point on a direct line from Kansas City to Dallas, and therefore represents fairly well the winds along most of this route.

A comparison of the average winds of this region with published reports for stations in other parts of the country indicates that the southern Plains States are somewhat peculiar in the large number of north and south winds compared to those from east or west. As will be seen in Figure 1, combined east and west winds at Broken Arrow amount to only 8 per cent while 44 per cent come from north or south. North and south winds also have a consierably higher average speed than east and west winds. The strongest wind is south and the weakest is east.

Published data show that as one proceeds northward along this route a somewhat higher average speed and an increasing percentage of a north component will be found in the surface winds.

TABLE 1.—*Average speed and frequency of wind at 1,600 feet*

| | Speed, m. p. h. | | | | | Frequency (per cent) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Spring | Summer | Autumn | Winter | Annual | Spring | Summer | Autumn | Winter | Annual |
| N | 22.1 | 12.8 | 20.1 | 22.1 | 19.3 | 6 | 3 | 8 | 9 | 7 |
| NNE | 16.8 | 14.1 | 19.0 | 20.6 | 17.6 | 6 | 3 | 7 | 7 | 6 |
| NE | 21.9 | 13.0 | 17.0 | 19.5 | 17.8 | 5 | 5 | 5 | 7 | 6 |
| ENE | 16.6 | 13.2 | 12.8 | 14.8 | 14.4 | 4 | 3 | 2 | 3 | 3 |
| E | 14.5 | 12.3 | 11.4 | 14.1 | 13.1 | 2 | 2 | 3 | 2 | 2 |
| ESE | 18.8 | 9.6 | 10.7 | 15.7 | 13.7 | 2 | 3 | 1 | 1 | 2 |
| SE | 18.8 | 12.5 | 9.8 | 18.6 | 14.9 | 4 | 4 | 3 | 2 | 3 |
| SSE | 21.7 | 14.1 | 18.3 | 18.1 | 18.0 | 7 | 8 | 7 | 4 | 6 |
| S | 28.4 | 18.8 | 21.7 | 21.9 | 22.7 | 16 | 17 | 16 | 7 | 14 |
| SSW | 31.5 | 24.4 | 26.6 | 29.3 | 28.0 | 18 | 21 | 18 | 14 | 18 |
| SW | 25.7 | 24.8 | 26.6 | 27.5 | 26.2 | 8 | 15 | 13 | 13 | 12 |
| WSW | 23.7 | 25.7 | 19.2 | 21.7 | 22.6 | 3 | 7 | 4 | 7 | 5 |
| W | 19.7 | 13.9 | 21.3 | 19.5 | 18.6 | 4 | 3 | 4 | 6 | 4 |
| WNW | 17.9 | 11.9 | 15.7 | 19.7 | 16.3 | 4 | 1 | 2 | 4 | 3 |
| NW | 20.4 | 14.1 | 18.8 | 17.2 | 17.6 | 4 | 2 | 3 | 8 | 4 |
| NNW | 20.8 | 12.3 | 21.5 | 23.0 | 19.4 | 7 | 3 | 4 | 6 | 5 |

Passing to the 1,600-foot (500-meter) level above the surface, which is considered as the average altitude of flight, we find that the greatest frequency of direction has shifted from the southeast to the southwest quadrant (fig. 2, Table 1). Forty-four per cent of all winds are from three directions—south to southwest. These are also the strongest winds, the highest average being 28 miles per hour from the SSW. Winds of least frequency and speed are easterly, the quadrant ENE. to SE. having a total of only 10 per cent and an average speed of 14 miles per hour. A secondary maximum both of frequency and speed is north and a secondary minimum is WNW.

Messrs. Gregg and Van Zandt have dealt in a most thorough manner with the wind factor along the transcontinental Air Mail route, and these works (*2*) should be consulted for a full discussion of the subject.

The transcontinental route, lying in an east-west direction, was found to have a resultant wind of 7.4 miles per hour from the west; this value agreed closely with the record of performance of the mail planes for the year. Along the southward extension of the Air Mail here considered resultant winds favor the south by practically the same amount. The resultant wind at Broken Arrow is S. 32° W., 8.7 miles per hour.

Substituting this value in the equations for resultant speed and direction of craft we find that over a north-south course a plane with a cruising speed of 100 miles per hour will have to make an angle of 2.5° with the course to overcome the effect of drift,

$$\sin \beta = \frac{8.7}{100} \sin 32^\circ.$$
$$\beta = 2.5^\circ.$$

The resultant or ground speed is, $S_r = 100 \cos 2.5 \pm 8.7 \cos 32$, or $100 \pm 7.4$. That is, southward flight will be made at a speed of 92.6 and northward flight at 107.4 miles per hour, a difference of 14.8.

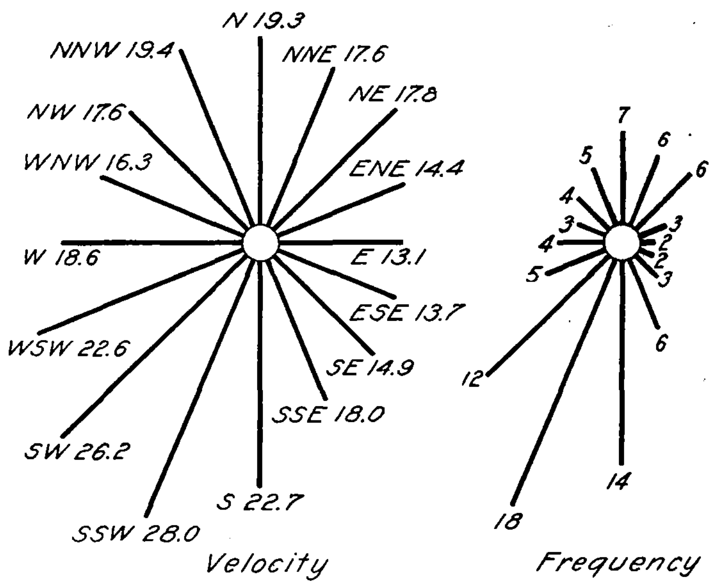


FIG. 2.—Average annual velocity (m. p. h.) and percentage frequency at 1,600 feet

The difference is slightly greater for a direct journey from Kansas City to Dallas because of the smaller angle this course makes with the resultant wind. Dallas is S. 16° W. from Kansas City, making 16° between wind and course. Respective speeds will therefore be 91.6 and 108.4 miles per hour.

Factors which affect the ability of a craft to maintain its schedule are the diurnal range of velocity and the frequency of strong winds. The diurnal range is shown in Figure 3, based on the average speed for each direction at 7 a. m. and 3 p. m. Clear columns indicate morning and shaded columns afternoon speeds. The values in this figure have been smoothed by the formula, $b = \frac{a + 2b + c}{4}$.

The morning observation shows typically nocturnal conditions, while the one at 3 p. m. occurs at the time of greatest diurnal effect. The two observations therefore show the extremes of the daily range.

One is accustomed to the fairly regular daily range in the surface wind but one is likely to be surprised at the magnitude and universality of the range at 1,600 feet. The changes at this level are just the reverse of those at the surface, for while surface winds are strongest during the day, free-air winds are strongest at night. The average difference for the year is 10 miles per hour and varies from 12 in summer to 8 in winter.

This daily range may also be seen in the resultant winds. In the morning the resultant is S. 38° W., 11.2 miles per hour and in the afternoon it is S. 23° W., 5.9 miles per hour.

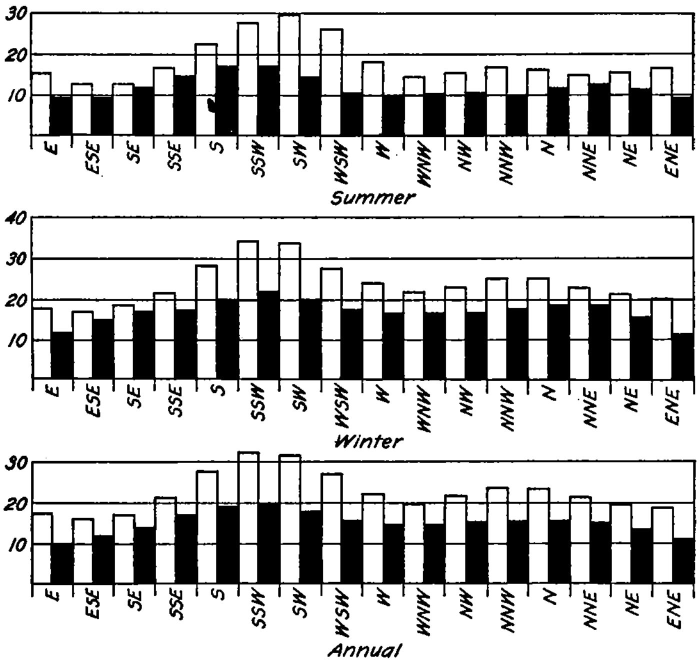


FIG. 3.—Average wind speed (m. p. h.) at 1,600 feet. Clear columns, 7 a. m., shaded columns, 3 p. m.

Winds from every direction are retarded during the day as shown by the seasonal and annual means in Figure 3. The greatest range occurs with the strongest winds, namely, those of the southwest quadrant. This is not because of slower speeds during the day but because the night winds from this quarter rise far above the average in speed. In summer, SSW. to WSW. winds vary from 28 miles per hour in the morning to 14 miles per hour in the afternoon; in winter, from 32 miles per hour in the morning to 20 in the afternoon.

The reason for the much stronger nocturnal free-air winds from the southwest is to be found in the vertical distribution of temperature. If the lapse rate exceeds the adiabatic rate the upper air, having a lower potential temperature, has a tendency to fall; mixing takes place and there is little stratification.

In a paper on "The relations between free-air temperatures and wind directions" Mr. Gregg has shown (*3*) that for the stations Drexel, Nebr., and Ellendale, N. Dak., the greatest lapse rate from the surface to the 500-meter level occurs in north and northwest winds and the least in SSW. to WSW. winds. Presumably much the same conditions hold for the southern Plains States.[2]

Southwest winds are therefore largely free from turbulence during the night and the free-air wind attains a high velocity with only a slight drag on the surface air. Conversely north winds, having a high lapse rate, undergo considerable mixing even at night with the result that strong winds are much less frequent.

These facts are emphasized by Figure 4, which gives the percentage frequency of strong winds occurring at flying levels in the morning. It will be noted that 78 per cent of all winds of 30 miles per hour or more and 88 per cent of all 40-mile winds, occur in the morning. This graph shows the very unequal distribution of strong winds from different directions. Most of them come from SSW. and adjacent directions, a moderate number from N. and NNW., while almost none comes from ESE. or WNW.

Ordinates on this graph show the frequency from each of the 16 points, while the total percentage for different speeds is given in the inset table. For instance, 30-mile winds occur in the morning 37 per cent of the time; they come from the one direction, SSW., 11 per cent of the time; from the three directions, south to southwest, 24 per cent; and from all other directions 13 per cent.

Forty-mile winds are half as frequent as 30-mile winds; they come from the SSW. alone 7 per cent of the time, from south to southwest 15 per cent, and from all other directions only 4 per cent. The preponderance of SSW. continues to increase with 50 and 60 mile winds; more than half of them being from this direction.

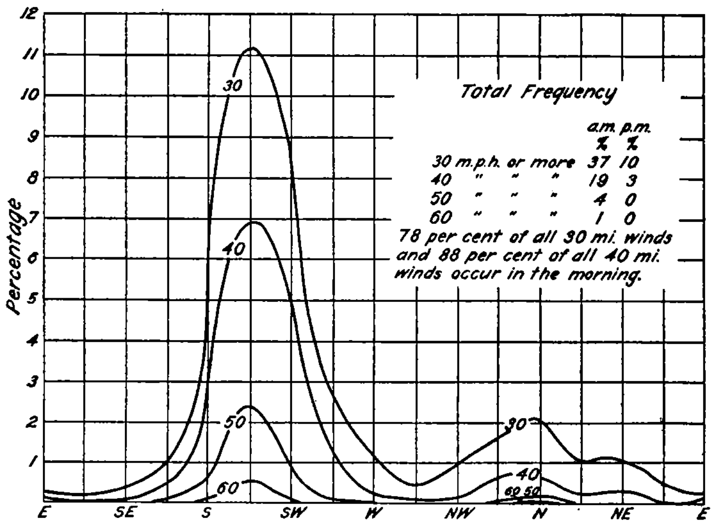


FIG. 4.—Percentage frequency of strong winds at 1,600 feet, based on daily observation at 7 a. m.

The total frequency of 50-mile winds is 4 per cent and of 60-mile winds less than 1 per cent. In other words, 30-mile winds occur in the morning about twice a week, 40-mile winds once a week, 50-mile winds once a month, and 60-mile winds about twice a year.

TABLE 2.—*Seasonal frequency, in percentages, of strong winds (a. m.)*

| | 30 miles per hour | 40 miles per hour | 50 miles per hour |
|---|---|---|---|
| Spring | 46 | 26 | 7 |
| Summer | 31 | 13 | 1 |
| Autumn | 36 | 20 | 3 |
| Winter | 36 | 19 | 6 |

As to the seasonal frequency of strong winds, spring stands preeminent; the least is of course in summer; autumn and winter are near the annual average (see Table 2).

March is the windiest month. The aviator should be warned to beware the winds of March. They are the "roaring forties"; the most frequent directions, south to southwest, have an average speed of 41 miles per hour.

Summer offers the best opportunity for selecting a favorable flying level. On account of the small average speed and diurnal range, a high altitude, probably around 3,000 feet, will occasionally be found most

[2] The same relationship between lapse rates in the lowest levels and surface wind directions is found in this region, although the variation is somewhat less pronounced. As at Drexel and Ellendale, the largest differences occur in winter and the smallest in summer.—*W. R. G.*

favorable. For while it frequently happens at all times of year that there is a layer of strong wind between 1,500 and 2,000 feet, with weaker winds above and below, the decrease aloft is generally small except in summer. In winter and spring the least resistance will generally be met by flying as low as practicable.

In conclusion it may be said that the southern plains States offer a favorable field for flying activities. The country is open and mostly free from mountains. Visibility, the most important meteorological element in flight, is generally satisfactory. On the visibility scale, running from zero for dense fog to 9 for perfectly clear air, the visibility most frequently recorded is 7. As an example of excellent visibility it may be cited that a pilot balloon at Broken Arrow was followed with two theodolites to a distance of more than 50 miles, and when the balloon disappeared it was less than 6° above the horizon.

Dense fog is the most serious obstacle but interruption of flight by dense fog in this region is very infrequent. Thunderstorms are a serious handicap; they cause delays by compelling the aviator to fly around them; statistics show, however, that thunderstorms are less frequent in this region than in some other States except perhaps in May and June. Low clouds and rain present the most frequent unfavorable condition, and often necessitate flying near the ground.

The schedule of the Air Mail for this portion of the route is so arranged as to gain the greatest benefit from the daily changes of wind; northward flight in the morning is frequently advanced by the prevailing strong south winds; southward flight is less frequently delayed in the afternoon because wind speeds are then at their lowest rates. The greatest percentage of delayed trips may be expected when southward trips are made in the early morning.

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## THE CORRELATION BETWEEN SUN-SPOT NUMBER AND TREE GROWTH

551.590.2 : 634

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There is at present evident, in both the scientific and the popular press, a widespread interest in the possible relationship between solar activity and terrestrial phenomena.

Such interrelationships, if they exist at all, can best be demonstrated and their intensity measured by the determination of the correlation between some measure of the sun's activity and terrestrial variables.

The only measure of solar activity available for a protracted period of time is that of the sun-spot relative numbers. The most usable measures of terrestrial phenomena which might possibly be influenced by solar variation are the instrumentally determined values of temperature, precipitation, barometric pressure, and other meteorological phenomena and the record of the rate of plant growth as embodied in the trunks of trees.

A review of the extensive literature on the supposed relationship between solar activity and climatic factors and plant activities falls quite outside the scope of the present note, which has for its purpose merely the presentation of the actual correlations between the annual means of the monthly observed relative sun-spot numbers ($s$) as given by Wolfer (*1*)[1] and the annual ring ($r$) measurements on trees from various parts of the world as given by Douglass (*2*).

Because of the great variability of both sun-spot numbers and ring diameters it is difficult to secure a system of grouping either variable which may not introduce an appreciable error into the end results. The coefficients of correlations, and the antecedent means and standard deviations, were computed from the original sun-spot numbers, $s$, of Wolfer and the ring measurements, $r$, of Douglass by the formula (*3*),

$$r_{sr} = [\Sigma(sr)\ /N - \bar{s}\ \bar{r})]\ /\ \sigma s\ \sigma r$$

without grouping of either of the variables. The coefficients are; therefore, numerically absolutely correct, barring the possibilities of arithmetical error which has not been detected in the checking of the coefficients.

The coefficients shown in the accompanying table[2] are generally low. Three of the fifteen values determined from the whole series of data are negative in sign. The ratios of the coefficients to these probable errors are over 2.00 in only 8 of the 15 cases.

TABLE I.—*Correlations between Wolfer's mean sun-spot relative numbers and tree-ring diameters as recorded by Douglass*

| Series and locality | Period | Correlation and probable error $r \pm E_r$ | $r/E_r$ |
|---|---|---|---|
| I. Flagstaff, Ariz. | 1749–1910 | +0.099±0.053 | +1.87 |
| II. South of England | 1859–1912 | +.265± .085 | +3.10 |
| III. Outer coast of Norway | 1828–1912 | +.174± .071 | +2.45 |
| IV. Inner coast of Norway | 1820–1908 | −.126± .070 | −1.79 |
| V. Christiania, Norway | 1820–1912 | +.071± .070 | +1.02 |
| VI. Central Sweden | 1820–1910 | +.109± .070 | +1.57 |
| VII. South Sweden | 1820–1910 | +.159± .069 | +2.30 |
| VIII. Eberswalde, Prussia | 1830–1912 | +.487± .056 | +8.64 |
| IX. Pilsen, Austria | 1830–1912 | +.096± .073 | +1.30 |
| X. Southern Bavaria | 1848–1911 | +.241± .079 | +3.04 |
| XI. Old Norway trees | 1749–1835 | −.164± .071 | −2.31 |
| XII. Old Sweden trees | 1749–1835 | +.317± .065 | +4.84 |
| XIII. Windsor, Vt. | 1749–1912 | −.076± .053 | −1.45 |
| XIV. Oregon group | 1749–1911 | +.157± .052 | +3.03 |
| XVI. Sequoia (group of 1915) | 1749–1914 | +.010± .053 | +0.19 |
| I. As above | 1749–1829 | +.073± .075 | +0.97 |
| I. As above | 1830–1910 | +.160± .073 | +2.19 |
| XIII. As above | 1749–1829 | −.272± .070 | −3.89 |
| XIII. As above | 1830–1912 | +.057± .074 | +0.77 |
| XIV. As above | 1749–1829 | +.395± .064 | +6.20 |
| XIV. As above | 1830–1911 | +.143± .073 | +1.97 |
| XVI. As above | 1749–1829 | +.091± .075 | +1.22 |
| XVI. As above | 1830–1914 | −.078± .073 | −1.07 |

There are, however, unmistakable evidences for a positive correlation between the two variables. While the coefficients are admittedly low, 12 of the 15 coefficients deduced for the series of data as given by Douglass are positive in sign. Of the eight values which are over twice

[1] The observed, not the smoothed, numbers were invariably used.

[2] The Series I–XVI correspond to the tables given in the appendix to Douglass's volume. The Series XV is omitted because it falls wholly outside the period of sun-spot record. The Series I, XIII, XIV, and XVI are treated both as entities and subdivided for reasons indicated in the text.